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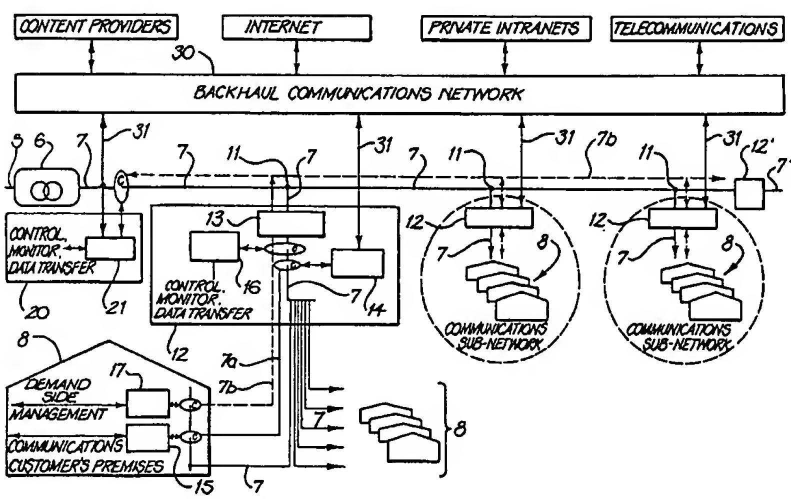

(57) Abstract: The power line communication system includes a distribution transformer having an electrical power feed cable for providing electrical power and having at least one distribution node connecting a plurality of clients to the electrical feed cable. A high speed (HS) head end is electrically disposed at the client distribution node and the feed cable passes through an isolation filter at the client distribution node to remove any high frequency modulated signals and to provide an isolated electrical feeder cable output. A HS head end HS power line communication (PLC) modem injects HS communication signals into the isolated feed cable. This PLC modem receives HS signals from a backhaul communication network and the feed cable branching to each client premises. A HS PLC modem located in the client's premises to extract the HS signals. The isolation filter electrically isolates any HS modulated signals from travelling back to the transformer side.

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POWERLINE COMMUNICATION SYSTEM

Field of the Invention

The present invention relates to a power line communication system such as an electricity power supply.

The invention has been developed for use in electricity power distribution networks and will be described hereinafter with reference to this particular application. However, it will be appreciated that the invention is not limited to this particular field of use.

Background of the Invention

Such an electricity power supply is generated at a generation voltage by a power station and transformed, if necessary, to a high voltage for distribution over a high voltage network. The high voltage network typically operates in the range of 150kV to 1.2MV. This high voltage distribution is provided to maximise the power transmission efficiency.

The high voltage distribution terminates at a medium voltage substation and thereafter the power is distributed over a medium voltage network which typically operates over a voltage range of 2.5kV to 150kV. The medium voltage network terminates at a low voltage distribution transformer which again steps down the voltage to the client supply voltage (which varies between different countries and different systems but is typically 110V to 415V).

Hitherto, in mains frequency power supplies the electric power utility is aware that the total energy it receives during a billing period from the transmission system exceeds by a considerable margin the total energy it bills of its clients for the billing period. Some of this discrepancy is able to be accounted for during distribution as technical losses or inefficiencies, for example, by resistive transmission losses, transformer losses, etc. However, much of the discrepancy is simply unable to be accounted for by the utility and is generally characterised as non-technical losses which includes unmetered services and fraud or theft. This represents a substantial financial loss for the utility.

Essentially the applicant appreciates that this discrepancy arises because hitherto it has not been possible to accurately measure and keep track of the flow of power (or energy) throughout the distribution system.

Electricity power distribution systems are also known to form bi-directional power line communication (PLC) networks, most often over the low voltage distribution network. Generally, a modulated carrier frequency is transmitted downstream of the distribution transformer which is able to be received by any of the premises downstream of the distribution transformer. In the low voltage networks, a large number of clients are all connected to a particular low voltage distribution transformer and share a predetermined signal bandwidth which is capable of being broadcast down the low voltage transmission lines. The data rate able to be transmitted by the low voltage network is of the order of 50 megabits per second. However, as all clients downstream of a low voltage distribution transformer share the same bandwidth, it is the case that data transfer rates to a client are limited to between 128 kilobits per second and 2.5 megabits per second. The data transfer rates to the clients fed from the distribution transformer decrease with increasing number of clients.

In so far as each of the clients on a side of a low voltage distribution transformer share the same available bandwidth or spectrum, this system is not useful for delivering high speed communications to each client, for example, in the form of video or interactive pay television services.

Ideally, an optical fibre network would co-exist with a power distribution system into the clients' premises to provide high speed communications capable of delivering video and interactive pay television services to, for example, up to 250 clients downstream of a low voltage distribution transformer. Unfortunately, this system is not presently commercially cost effective and so is not likely to be practically realised.

In existing power line communication (PLC) system topologies, a "head end" unit is installed at the medium to low voltage distribution transformer. Upstream of the head end is a communications medium which takes a variety of forms including fibre optic cable and coaxial cable. The head end downstream communications medium is the low voltage power

feed cable network that connects the low voltage distribution transformer to each of the power consumers.

This power line communication system is used to communicate between the head end and any number of the PLC clients that are connected to the low voltage distribution transformer, commonly 250 in Australia. A PLC modem in the head end is used to modulate and demodulate the data signals into the power lines of the low voltage distribution transformer. A similar PLC modem is connected to the power lines at each of the PLC systems client's premises so as to form a bi-directional communications link between the head end and each PLC client.

Low voltage power line cable is used in existing PLC systems and sets the limitation by its physical nature that only a limited range of signal modulated frequencies are capable of being propagated over a sufficient distance of cable to make these PLC systems practical. As noted above, this limitation translates into a bandwidth limitation which sets an upper limit for the data transfer rate that can be supported by the PLC system.

These known PLC systems suffer from the disadvantages that the total data transmission rates to the clients supported by the PLC modem at the system's head end is shared amongst all clients. If only a very small percentage of clients happen to be connected via the power distribution system to the PLC system, relatively high data rates are available. However, such few clients would make such a system completely unviable with today's demand for high speed data transmission, particularly the increasing demand for video and interactive pay television services.

The presence of imperfect transmission line matching at junctions and connections to the low voltage feeder network reduces the available signal to noise ratio at the receivers in a PLC system. This reduction is coupled with the common physical condition of substantial signal attenuation where the head end and PLC clients can be separated by relatively large distances.

A plurality of PLC repeaters are generally necessary to be installed along the low voltage feeder network to ensure that the PLC clients will be able to establish communications of a sufficient predetermined quality to the head end to make such a PLC system viable.

Existing PLC systems also suffer from the disadvantage that they are susceptible to electrical noise generated by power consumers, lightening strikes, switching or feed cable maintenance. Such interference can cause a reduction in the signal to noise ratio of the PLC transceivers for the large number of clients connected to the low voltage feeder network downstream of the low voltage distribution transformer.

Several efforts have been made to address these problems which to date have only been bit-part solutions applied to individual problems in existing PLC systems. For example, US Patent Nos. 5,892,795 and 5,870,016 and European Patent Application No. 1,189,420 each describe a system in which the transmission signal is conditioned with a modem to more efficiently communicate the PLC signals. However, these systems are still limited in bandwidth available to clients and are susceptible to interference.

International Patent Application No. WO 89/03623 describes a low speed PLC system including a low pass filter network installed at a low voltage distribution transformer to reduce the PLC system's susceptibility to interference. The low pass filter prevents communication signals from passing directly from the supply authority to the consumers at the low voltage distribution transformer. In addition, high frequency noise generated on the low voltage network is prevented from reaching the supply authority's side of the transformer. The low pass filter can be integrated with a current transformer to measure power consumption and modulated signals are capable of being injected to the supply lines via the filter at the low voltage distribution transformer.

However, the system of this prior art patent application is primarily disadvantageous in not addressing the problem that a large number of consumers downstream of each low voltage distribution transformer on a low voltage distribution network share the available bandwidth or spectrum.

Japanese Patent Application No. 2001 094483 discloses a system for isolating an indoor PLC network from the supply authority's power cabling network by using a blocking filter. The indoor terminals communicate to a telecommunications controller located at a switchboard. The telecommunications controller serves a variety of functions such as a gateway between the

indoor PLC network and other communication media, as a server for the indoor terminals and as a communication mode for an external PLC.

Unfortunately, the system of this prior art patent specification only discloses a blocking filter which is useful at the client's premises and which employs high frequency communications. This system does not address the existing problems of insufficient high speed communications signal bandwidth or susceptibility of the signals to external interference.

Object of the Invention

It is an object of the present invention to provide a power line communications system which overcomes or substantially ameliorates at least some of the problems of the prior art, or provides a useful alternative.

Summary of the Invention

According to a first aspect of the invention there is provided a power line communication system including:

a distribution transformer having an electrical power feed cable for providing electrical power, the electrical feed cable having at least one distribution node connecting a plurality of clients to the electrical feed cable;

a high speed (HS) head end electrically disposed at the client distribution node, the electrical feed cable passing through an isolation filter at the client distribution node to remove any high frequency modulated signals and to provide an isolated electrical feeder cable output;

a HS head end HS power line communication (PLC) modem output in electrical communication with the isolated electrical feed cable to inject HS communication signals into the isolated feed cable, the HS PLC modem receiving HS communication signal input from a backhaul communication network and, the isolated electrical feed cable branching to each client premises;

a HS PLC modem located in the client's premises to extract the HS communication signal from the isolated feed cable and form a bi-directional network with the HS head end HS PLC modem; and

wherein the isolation filter electrically isolates any HS modulated signals from travelling back from the client's side of the client distribution node to the transformer side.

In preferred embodiments, the power line communication system further includes a low speed (LS) head end electrically disposed on the electrical feed cable side of the distribution transformer, the LS head end including a LS PLC modem in communication with the backhaul network to transmit and receive low speed communications signals and in communication with the electrical feed cable to receive or transmit low speed communication signals therealong, the low speed communication signals being a non-overlapping frequency to the HS signals to pass through the isolation filter and provide LS communication signal downstream at, and downstream of, each distribution node.

Preferably, the distribution transformer is a medium voltage to low voltage distribution transformer for providing low voltage mains frequency electrical power.

Preferably, the LS head end controls and monitors the operation of the HS head end by communication with a LS PLC modem in the HS head end and the LS and HS head ends communicate via low voltage mains electrical feed cable or other conventional low speed communication means.

In preferred embodiments, a LS head end is electrically disposed on the low voltage mains frequency electrical power feed cable side of each of a plurality of the low voltage distribution transformers in the system, each LS head end being in LS communication with a system controller for controlling any HS head ends located at client distribution nodes in mains electrical feed cable.

Preferably, the LS and HS head ends control, monitor and reconcile mains electricity power consumption from the mains electrical feed cable, the LS head end transmitting an LS signal to the system controller indicative of the LS and HS head end monitoring and reconciliation, and the HS head ends include a controller and energy metering means.

In preferred embodiments, the LS PLC communication signals are extracted from the mains electrical feed cable at the client premises by a LS PLC modem forming a bi-directional LS communications network with the LS PLC modem in the HS head end over the mains electrical feed cable to the client premises.

Preferably, the LS PLC communication signals are extracted from the mains electrical feed cable at the client premises by a LS PLC modem forming a bi-direction LS communication network with the LS head end LS PLC modem.

Preferably, and wherein the LS head ends and HS head ends communicate with the backhaul communications network via any one or a combination of the following media, protocols, or techniques: fibre optic cable, free space optical communication, hybrid fibre-coaxial cable, digital line subscriber, ethernet, public switch telephone networks, power line communications or wire line. In alternative preferred embodiments, the LS and HS head ends communicate with the backhaul communications network by RF signals transmitted in freespace therebetween.

In preferred embodiments, the mains electrical feed cable extending from the HS head end to each client's premises is configured so that each mains electrical feed cable into each premises are electrically in parallel with each other downstream of the HS head end, or the mains electrical feed cable to the client's premises are connected in a series or daisy chain configuration. More preferably, the low voltage distribution transformer and mains electricity feeder cable to each client's premises are part of a pre-existing power transmission network.

Preferably, the electrical feeder cable isolated for each group of client premises downstream of the HS head ends by the isolation filter forms a local area network (LAN) permitting frequency re-use along the electrical feed cable on the transformer side of the distribution node. Also preferably, the power distribution system includes one or more secondary HS head ends located at one or more client premises to establish one or more secondary LANs within the mains electricity feeder cables on the client's premises.

In preferred embodiments, a HS head end is disposed on the distribution transformer electrical feed cable passing through the HS head end isolation filter to form a LAN in the electrical feed cable downstream. More preferably, a HS head end is electrically disposed at the at least one client distribution node downstream of the HS head end disposed in the distribution transformer feed cable.

According to a second aspect of the invention there is provided a method of providing a powerline communication system, the method including the steps of:

providing electrical power to an electrical feed cable system downstream of a distribution transformer;

connecting the electrical feed cable to a plurality of client's premises via one or more distribution nodes disposed along the electrical feed cable;

feeding groups of a plurality of client premises via the electrical feed cable from each distribution node;

filtering the electrical feed cable at a high speed (HS) head end disposed electrically intermediate the client distribution nodes and client premises by means of an isolation filter which prohibits the transmission of high speed communication signals through the node back into the electrical feed cable;

injecting high speed communication signals for use by the client into the isolated electrical feed cable at the high speed head end; and

extracting the high speed communication signals at a client premises from the mains electricity feed cable thereto.

Preferably, the step of injecting and extracting the high speed communication signal is effected by a HS PLC modem at the client's premises and the HS head end, the HS PLC modems forming a bi-directional communication network therebetween.

In preferred embodiments, the method further includes the steps of:

providing a LS head end in the electrical feed system downstream of the distribution transformer;

providing a LS PLC modem in the LS head end, the LS PLC modem being in communication with a backhaul network to transmit and receive low speed communication signals and in communication with the electrical feed cable to receive and transmit low speed communication signals therealong;

transmitting the LS communication signals along the electrical feeder cable to each client premises via the isolation filter of each HS head end;

providing LS communication signal downstream at and downstream of each distribution node; and

controlling and monitoring the operation of the HS head end from the LS head end.

Preferably, the distribution transformer is a medium to low voltage distribution transformer for providing low voltage electrical power.

In preferred embodiments, the method further includes the step of electrically disposing a LS head end on the mains electricity feed side of each of a plurality of low voltage distribution transformers, and providing communications between each LS head end and a system controller by LS communications for controlling the HS head ends.

In preferred embodiments, the method further includes the step of monitoring mains electricity power usage at the HS and LS head ends and reconciling power use therebetween and transmitting a report to the system controller by the LS head ends of the mains electricity power consumption.

Preferably, the method further includes the step of connecting a backhaul communications network to the LS head ends and HS head ends, the backhaul network including any one or combination of the following media, protocols or techniques fibre optic cable, free space optical communication, hybrid fibre-coaxial cable, digital line subscriber, ethernet, public switch telephone network or power line communications. Alternatively, the method further includes the step of connecting the LS and HS head ends to a backhaul communication network for communication therebetween by means of RF communications.

Preferably, the mains electricity feeder cables between the distribution transformer and the client's premises are part of a pre-existing power distribution system. More preferably, the step of forming a HS LAN between the clients downstream of the HS head end and the method further includes the step of forming a secondary HS LAN over the mains electricity cable within the client's premises.

In preferred embodiments, the method includes the step of disposing a HS head end in the distribution transformer electrical feed cable such that it passes through the HS head end isolation filter to form a LAN in all the electrical feed cable downstream.

Preferably, the method includes the step of disposing a HS head end at at least one distribution node downstream of the HS head end disposed in the distribution transformer electrical feed cable.

In preferred embodiments, the method further includes the step of reusing HS communication signal spectrum along the electrical feed cable downstream of the high speed head end at the power distribution node.

Thus, the present invention advantageously permits PLC system line testing, performance testing, maintenance and fault finding to be conducted on an isolated PLC sub-network without disrupting HS PLC in other sub-networks. Further, any HS signals generated or transmitted in an isolated PLC communications sub-network will be prevented from interfering with other PLC sub-networks. The present invention also permits the transfer of low frequency ripple signals that are used by the utility company in the process of load control.

Brief Description of the Drawings

Preferred embodiments will now be described, by way of example only, with reference to the drawings in which:

FIG 1 is a schematic illustration of a convention power distribution system;

FIG 2 schematically illustrates a power distribution system according to an embodiment;

FIGs 3 to 5 illustrate different embodiments of the system of FIG 2;

FIG 6 illustrates a HS head end for use in the embodiment of FIG 3;

FIG 7 illustrates a HS head end for use in the embodiment of FIG 4;

FIG 8 illustrates an EPQM meter;

FIG 9 illustrates a LS head end;

FIG 10 illustrates an overview of the embodiment of FIG 2; and

FIG 11 illustrates a device 70 for use in the embodiment of FIG 2.

Detailed Description of the Preferred Embodiments

Referring to FIG 1, there is illustrated a typical electrical power distribution system 1. A high voltage network 3 distributes power from the power station 2, the power being transmitted at a high voltage, typically between 150kV to 1.2MV to minimise resistive losses. The high

voltage network 3 terminates at a medium voltage substation 4 where the power is distributed over a medium voltage network 5, typically the order of 2.5kV to 150kV. The medium voltage network 5 terminates at low voltage distribution transformer 6 which steps down the voltage to the client supply voltage, typically in the order of 110V to 415V. A low voltage power feed cable network 7 transmits the low voltage electrical power to the utility clients 8.

The mains feed cable 7 includes at least one distribution node 11 which connects a group of a plurality of utility clients' premises 8 to the low voltage mains supply.

Referring to FIG 2, there is schematically illustrated a power line communications system 10 in accordance with a preferred embodiment. The mains electricity feed cable 7 travels from the low voltage distribution transformer 6 to each utility client 8 in the low voltage network. The power line communications system 10 can also be employed in a network of any voltage including high and medium voltage distribution networks.

A group of a plurality of client premises are electrically connected to the mains electricity feed cable 7 at distribution nodes 11. FIG 2 illustrates three groups of client premises 8 connected at 3 distribution nodes 11 disposed from the mains electricity feed cable 7. Each low voltage distribution transformer 6 typically includes 30 to 150 client premises which would typically have between 5 and 30 client distribution nodes.

A high speed head end 12 is electrically disposed at each client distribution node. The mains electricity feed cable 7 enters the HS head end 12 and passes through an isolation filter 13 which removes any high frequency modulated signal to provide an isolated mains electrical feeder cable 7 which extends to each client's premises in the distribution node. The isolation filter 13 can be separate to or integrated with the HS head end 12.

The HS head end 12 includes a HS PLC modem 14 in communication with the mains frequency feed cable 7 to transmit or receive HS communication signals to or from the mains feed cable 7. These high speed communication signals can only travel on the client premises side of the isolation filter 13. The HS PLC modem 14 is coupled to the feed cable 7 by any convention means, and can be either remote from or integrated with the HS head end 12.

A HS PLC modem 15 is located in the client's premises 8 to extract or receive a HS communication signal and form a bi-directional network with the HS head end 12 HS PLC modem 14 over the isolated mains electrical feed cable 7. It is noted that the HS PLC modulated signal line is shown in small dotted lines and referenced 7a and is only shown separated from feed cable 7 for illustration purposes.

The HS head end 12 HS PLC modem 14 communicates with a backhaul communication network 30 for receiving and transmitting HS data therebetween. The backhaul communications network 30 and HS PLC modem 14 communicate via any one or a combination of the following media, protocols or techniques 31: fibre optic cable, free space optical communication, hybrid fibre-coaxial cable, digital line subscriber, ethernet, public switch telephone networks, powerline communications or wire line, for example. FIG 3, for example, illustrates a fibre optical cable 33 which connects the backhaul communications network and communicates with the HS PLC modem 14.

FIG 4 illustrates an example where the HS PLC modem 14 communicates with the backhaul communications network 30 by means of a HS communications link provided with the backhaul communications network 31 via the mains electricity feed cable 7 only on the low voltage distribution transformer of the low voltage network. These high frequency signals are not propagated through the isolation filter 13 in the HS head end 12.

The system 10 further includes a LS head end 20 electrically disposed on the mains electrical feed cable 7 intermediate the low voltage distribution transformer and any distribution nodes 11 in the feed cable 7. The LS head end 20 includes a LS PLC modem 21 which is in communication with the backhaul network 30 via any conventional means 31, for example as described above, to transmit and receive LS communication signals.

The LS PLC modem 21 is also in communication with the low voltage mains electrical feed cable 7 to receive and transmit LS communication signals therealong. The LS communication signals are transmitted along the mains electrical feeder cable 7 through distribution nodes 11 and through the isolation filter 13 of the HS head end 12. The LS PLC modem 21 signals are transmitted through the isolation filters 13 and are received by a LS PLC modem 16 in the HS head end 12. The LS PLC modem 16 and the HS head end 12 can communicate with the LS

PLC modem 21 as well as with an LS PLC modem 17 located in the client's premises. The LS PLC modulated signals, shown by dashed line 7b travel down the mains electrical feed line 7 to the client premises, communicate with the LS PLC modem 17. The LS head end 20 controls and monitors the operation of the HS head ends 12 which in turn controls and monitors the operation of the HS PLC modems 14 and mains electricity transmitted through electrical feeder cable 7. The LS head end also forms a bi-directional LS communications network directly with the client's premises.

The LS PLC modulated signals generated at the LS head end 20, can alternatively be transmitted to the HS head ends 12 by wireline or other conventional media protocols or techniques.

The LS head end 20 and HS head ends 12 monitor the flow of electricity in the low voltage electricity distribution network. The HS head ends 12 transmit this data to the LS head end 20 via LS PLC modulated signals wherein the LS head end 20 communicates with a system controller 60 in communication via the backhaul communications network 30.

In this way, the electricity utility can monitor the power distribution to each client at the LS head end 20, HS head end 12 and client premises 8 to more accurately determine and report the location of any faults, perform energy reconciliation of energy delivered against energy consumed, determined any losses as well as to more accurately monitor the power consumption needs of each client. The HS head ends 12 can include an energy metering means.

The LS PLC modulated signals also provide control information to the HS head ends 12 as well as client premises 8 via the LS PLC modem 17.

The mains electricity feed cable 7 extends from the HS head ends 12 at the distribution node 11 to each of the client's premises wherein the cables 7 are electrically in parallel. In other embodiments (not illustrated) the client premises 8 are connected electrically in series to the mains electrical feed cable 7. Therefore, each group of client premises 8 electrically downstream of a HS head end 12 form a local area network (LAN).

Each of these LANs is isolated from other networks by means of the isolation filter 13 in each HS head end 12. That is, HS communication signals transmitted through the means electricity feed cable 7 are isolated from the means electrical feed cable 7 upstream of the isolation filter 13. In one implementation, frequency division multiplexing is used in the HS communications signalling.

FIG 6 illustrates an embodiment of a HS head end 12 used in the embodiment illustrated in FIG 3 wherein the HS communication signals are transmitted to the backhaul network via optical fibre network 33 disposed physically in parallel with the mains electricity feeder cable 7 located on the low voltage distribution transformer side of the distribution nodes 11. The HS head end 12 includes power supply and surge suppressor 40, a HS head end controller 41 and a router 42. A user interface 43 in the form a display and key panel are also provided.

FIG 7 illustrates another embodiment of a HS head end 12 which receives and transmits the HS communication signals from the mains electrical feeder 7. A pair of isolation filters 45 in the form of low pass filters are provided to isolate sections of the electrical feed cable 7 between the distributions nodes 11 thereby permitting carrier frequency re-use over the main electrical feed cable 7.

As best illustrated in FIG 2, the system 10 also includes a HS head end 12' disposed in the distribution transformer electrical feed cable 7 and passing through the HS head end isolation filter (not illustrated) to form a LAN in the electrical feed cable 7' downstream. The LAN formed by the HS head end 12' in electrical feed cable 7' can include one or more other HS head ends 12 disposed in the feed cable 7' or at client distribution nodes downstream. It can be seen that any number of desired HS head end LANs can be formed.

The HS head ends illustrated in FIGs 6 and 7 include an energy and power quality meter module 48 (EPQM module) which is shown schematically in a general form in FIG 8. The EPQM module 48 includes an energy meter for calculating an accumulated cost to a particular client premises 8 connected to each HS head end 12.

The LS head end 20, an embodiment having an EPQM meter 48, is shown in FIG 9. The LS head end 20 schematically illustrated includes an RF communications link (but can be any

medium) to the backhaul communications 30. The LS head end 20 includes EPQM meter 48 of the type illustrated in FIG 8 for monitoring the flow of power downstream of the low voltage distribution transformer 6. The power consumption data collected by the EPQM meters in the LS and HS head ends is transmitted to the system controller 60 so that an accurate determination of power consumption and any losses in the low voltage network can be established.

FIG 10 shows a schematic illustration of the LS and HS modulated signal communication network. The modulated signals are transmitted between the LS head end 20 by any conventional means 31 to a backhaul communication network 30. The system controller 60 is in communication with the LS head end 20 by conventional means 31 over public networks and a WAN as illustrated.

Referring to FIG 11, there is illustrated a schematic embodiment of a device 70 for connection to the mains feeder cable 7 at the client's premises. The device 70 includes a low voltage input 7 from which HS PLC and LS PLC modulated signals are extracted by HS PLC modem 15 and LS PLC modem 17. The HS or LS signals are then transmitted through a metering platform controller 71 to a communications output 72. The mains electricity power is transferred through the EPQM 48 module to an electrical appliance connected thereto and having an electrical contactor or contactors 73 therebetween. The EPQM 48 measures the appliance energy consumptions and other parameters which are then transmitted back to either or both the HS head end 12 and the LS head end 20 for demand side management.

In the power distribution system embodiments described and illustrated, it can be seen that HS communication signals can be efficiently transmitted to client premises via mains electricity feed cable. Data transfer rates of greater than 35Mbps can be achieved and all clients on one side of a distribution node and isolated through an isolation filter, can form a LAN over the power distribution cables. Carrier frequencies of the order of 1 to 40 megahertz can be used in the system.

Therefore, the system 10 is suitable for the communication of video and interactive pay television services, in addition to telephony and high and low speed internet services. In addition, the system 10 provides for the controlling, monitoring and reconciliation of power

consumption through a power distribution network. This controlling, monitoring and reconciliation can be used by the utilities to monitor and isolate, if necessary, areas of high electricity peak demand as well as disconnect delinquent clients, attend to connections and disconnections and detect the presence of fraud. The distribution system 10 is particularly advantageous for use industrial estates and high rise buildings as well as specialised clients such as airports, railways and high tech manufacturers.

In some of the embodiments described, more than a thousand HS PLC sub-carrier modulated frequencies can be employed in one frequency band, where each carrier is independently modulated with a fraction of the total data transfer rate. In a single frequency band, data rates of between 50 to 100 Mbps can be achieved between the backhaul communications network 30 and the client's premises 8.

The foregoing describes only a preferred embodiment of the present invention and modifications, obvious to those skilled in the art, can be made thereto without departing from the scope of the present invention.

CLAIMS

1. A power line communication system including:

a distribution transformer having an electrical power feed cable for providing electrical power, the electrical feed cable having at least one distribution node connecting a plurality of clients to the electrical feed cable;

a high speed (HS) head end electrically disposed at the client distribution node, the electrical feed cable passing through an isolation filter at the client distribution node to remove any high frequency modulated signals and to provide an isolated electrical feeder cable output;

a HS head end HS power line communication (PLC) modem output in electrical communication with the isolated electrical feed cable to inject HS communication signals into the isolated feed cable, the HS PLC modem receiving HS communication signal input from a backhaul communication network and, the isolated electrical feed cable branching to each client premises;

a HS PLC modem located in the client's premises to extract the HS communication signal from the isolated feed cable and form a bi-directional network with the HS head end HS PLC modem; and

wherein the isolation filter electrically isolates any HS modulated signals from travelling back from the client's side of the client distribution node to the transformer side.

2. A power line communication system according to claim 1 further including a low speed (LS) head end electrically disposed on the electrical feed cable side of the distribution transformer, the LS head end including a LS PLC modem in communication with the backhaul network to transmit and receive low speed communications signals and in communication with the electrical feed cable to receive or transmit low speed communication signals therealong, the low speed communication signals being a non-overlapping frequency to the HS signals to pass through the isolation filter and provide LS communication signal downstream at, and downstream of, each distribution node.

3. A powerline communication system according to claim 1 or 2 wherein the distribution transformer is a medium voltage to low voltage distribution transformer for providing low voltage mains frequency electrical power.

4. A powerline communication system according to claim 3 wherein the LS head end controls and monitors the operation of the HS head end by communication with a LS PLC modem in the HS head end.

5. A powerline communication system according to claim 4 wherein the LS and HS head ends communicate via low voltage mains electrical feed cable or other conventional low speed communication means.

6. A powerline communication system according to claim 4 or 5 wherein a LS head end is electrically disposed on the low voltage mains frequency electrical power feed cable side of each of a plurality of the low voltage distribution transformers in the system, each LS head end being in LS communication with a system controller for controlling any HS head ends located at client distribution nodes in mains electrical feed cable.

7. A powerline communication system according to claim 6 wherein the LS and HS head ends control, monitor and reconcile mains electricity power consumption from the mains electrical feed cable, the LS head end transmitting an LS signal to the system controller indicative of the LS and HS head end monitoring and reconciliation.

8. A powerline communication system according to claim 7 wherein the HS head ends include a controller and energy metering means.

9. A powerline communication system according to claim 8 wherein the LS PLC communication signals are extracted from the mains electrical feed cable at the client premises by a LS PLC modem forming a bi-directional LS communications network with the LS PLC modem in the HS head end over the mains electrical feed cable to the client premises.

10. A powerline communication system according to claim 8 wherein the LS PLC communication signals are extracted from the mains electrical feed cable at the client premises by a LS PLC modem forming a bi-direction LS communication network with the LS head end LS PLC modem.

11. A powerline communication system according to any one of claims 3 to 10 wherein the LS head ends and HS head ends communicate with the backhaul communications network via any one or a combination of the following media, protocols, or techniques:

fibre optic cable, free space optical communication, hybrid fibre-coaxial cable, digital line subscriber, ethernet, public switch telephone networks, power line communications or wire line.

12. A powerline communication system according to any one of claims 3 to 10 wherein the LS and HS head ends communicate with the backhaul communications network by RF signals transmitted in freespace therebetween.

13. A powerline communication system according to any one of claims 3 to 12 wherein the mains electrical feed cable extending from the HS head end to each client's premises is

configured so that each mains electrical feed cable into each premises are electrically in parallel with each other downstream of the HS head end, or the mains electrical feed cable to the client's premises are connected in a series or daisy chain configuration.

14. A power distribution system according to any one of claims 3 to 13 wherein the low voltage distribution transformer and mains electricity feeder cable to each client's premises are part of a pre-existing power transmission network.

15. A power distribution system according to any one of the preceding claims wherein the electrical feeder cable isolated for each group of client premises downstream of the HS head ends by the isolation filter forms a local area network (LAN) permitting frequency re-use along the electrical feed cable on the transformer side of the distribution node.

16. A power distribution system according to any one of the preceding claims including one or more secondary HS head ends located at one or more client premises to establish one or more secondary LANs within the mains electricity feeder cables on the client's premises.

17. A power distribution system according to any of the preceding claims including a HS head end disposed on the distribution transformer electrical feed cable passing through the HS head end isolation filter to form a LAN in the electrical feed cable downstream.

18. A power distribution system according to claim 17 including a HS head end electrical disposed at at least one client distribution node downstream of the HS head end disposed in the distribution transformer feed cable.

19. A method of providing a powerline communication system, the method including the steps of:

providing electrical power to an electrical feed cable system downstream of a distribution transformer;

connecting the electrical feed cable to a plurality of client's premises via one or more distribution nodes disposed along the electrical feed cable;

feeding groups of a plurality of client premises via the electrical feed cable from each distribution node;

filtering the electrical feed cable at a high speed (HS) head end disposed electrically intermediate the client distribution nodes and client premises by means of an isolation filter which prohibits the transmission of high speed communication signals through the node back into the electrical feed cable;

injecting high speed communication signals for use by the client into the isolated electrical feed cable at the high speed head end; and

extracting the high speed communication signals at a client premises from the mains electricity feed cable thereto.

20. A method according to claim 19 wherein the step of injecting and extracting the high speed communication signal is effected by a HS PLC modem at the client's premises and the HS head end, the HS PLC modems forming a bi-directional communication network therebetween.

21. A method according to claim 19 or 20 including the steps of:

providing a LS head end in the electrical feed system downstream of the distribution transformer;

providing a LS PLC modem in the LS head end, the LS PLC modem being in communication with a backhaul network to transmit and receive low speed communication signals and in communication with the electrical feed cable to receive and transmit low speed communication signals therealong;

transmitting the LS communication signals along the electrical feeder cable to each client premises via the isolation filter of each HS head end;

providing LS communication signal downstream at and downstream of each distribution node; and

controlling and monitoring the operation of the HS head end from the LS head end.

22. A method according to claim 20 or 21 wherein the distribution transformer is a medium to low voltage distribution transformer for providing low voltage electrical power.

23. A method according to claim 22 including the step of electrically disposing a LS head end on the mains electricity feed side of each of a plurality of low voltage distribution transformers, and providing communications between each LS head end and a system controller by LS communications for controlling the HS head ends.

24. A method according to claim 23 including the step of monitoring mains electricity power usage at the HS and LS head ends and reconciling power use therebetween; and

transmitting a report to the system controller by the LS head ends of the mains electricity power consumption.

25. A method according to any one of claims 21 to 24 including the step of connecting a backhaul communications network to the LS head ends and HS head ends, the backhaul network including any one or combination of the following media, protocols or techniques:

fibre optic cable, free space optical communication, hybrid fibre-coaxial cable, digital line subscriber, ethernet, public switch telephone network or power line communications.

26. A method according to any one of claims 21 to 24 including the step of connecting the LS and HS head ends to a backhaul communication network for communication therebetween by means of RF communications.

27. A method according to claim 25 or 26 wherein the step of connecting the group of a plurality client premises to the HS head end is effected by electrically disposing each premises electrically in parallel to the mains electricity feed cable from the HS head end, or disposing the mains electricity feeder cable and each client premises in a series or daisy chain arrangement.

28. A method according to any one of claims 19 to 27 wherein the mains electricity feed cables between the distribution transformer and the client's premises are part of a pre-existing power distribution system.

29. A method according to any one of claims 19 to 28 including the step of forming a HS LAN between the clients downstream of the HS head end.

30. A method according to any one of claims 19 to 29 including the step of forming a secondary HS LAN over the mains electricity cable within the client's premises.

31. A method according to any one of claims 19 to 30 including the step of disposing a HS head end in the distribution transformer electrical feed cable such that it passes through the HS head end isolation filter to form a LAN in all the electrical feed cable downstream.

32. A method according to claim 31 including the step of disposing a HS head end at at least one distribution node downstream of the HS head end disposed in the distribution transformer electrical feed cable.

33. A method according to any one of claims 19 to 32 including the step of reusing HS communication signal along the electrical feed cable bandwidth or spectrum downstream of the high speed head end at the power distribution node.

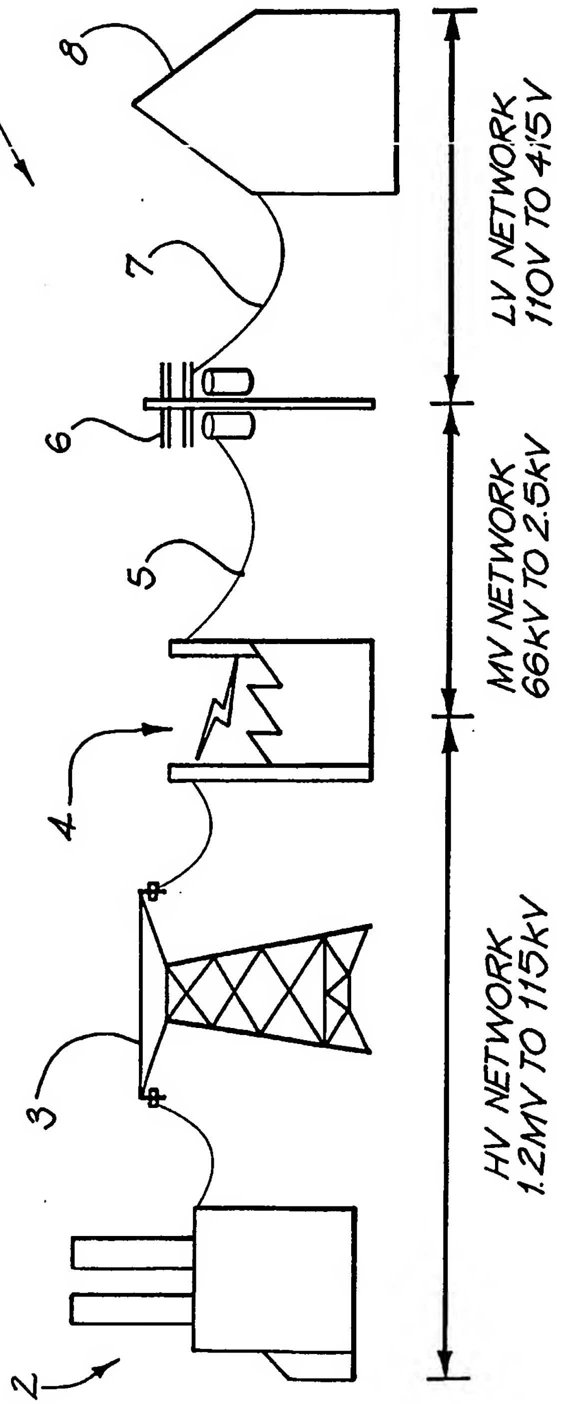
1
2
3
4
5
6
7
8
LV NETWORK
110V TO 415V
MV NETWORK
66kV TO 2.5kV
HV NETWORK
1.2MV TO 115kV

FIG. 1

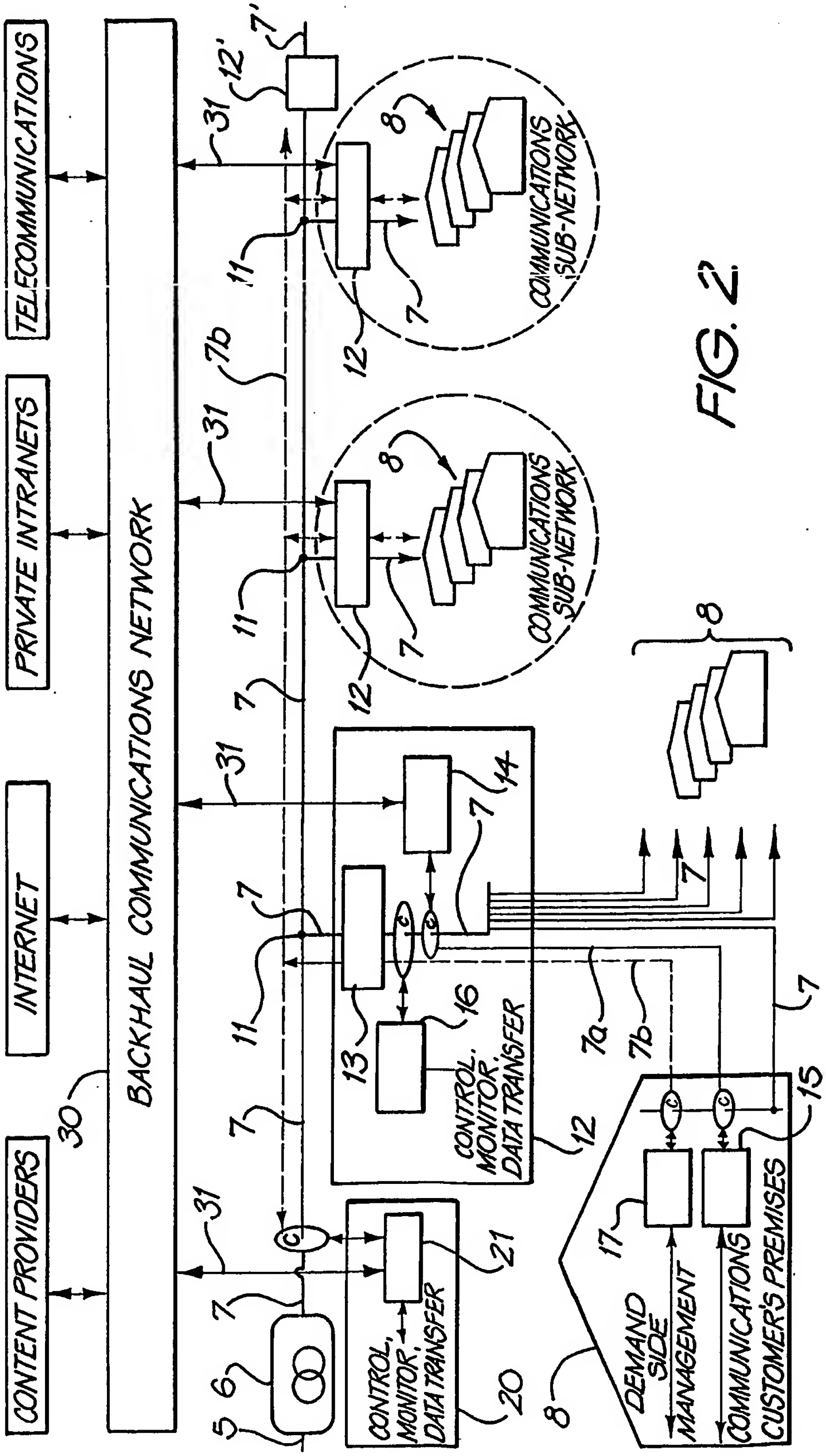
CONTENT PROVIDERS
INTERNET
PRIVATE INTRANETS
TELECOMMUNICATIONS
BACKHAUL COMMUNICATIONS NETWORK
COMMUNICATIONS SUB-NETWORK
COMMUNICATIONS SUB-NETWORK
CONTROL, MONITOR, DATA TRANSFER
CONTROL, MONITOR, DATA TRANSFER
DEMAND SIDE MANAGEMENT
COMMUNICATIONS CUSTOMER'S PREMISES
5
6
7
7'
7a
7b
8
11
12
12'
13
14
15
16
17
20
21
30
31

FIG. 2

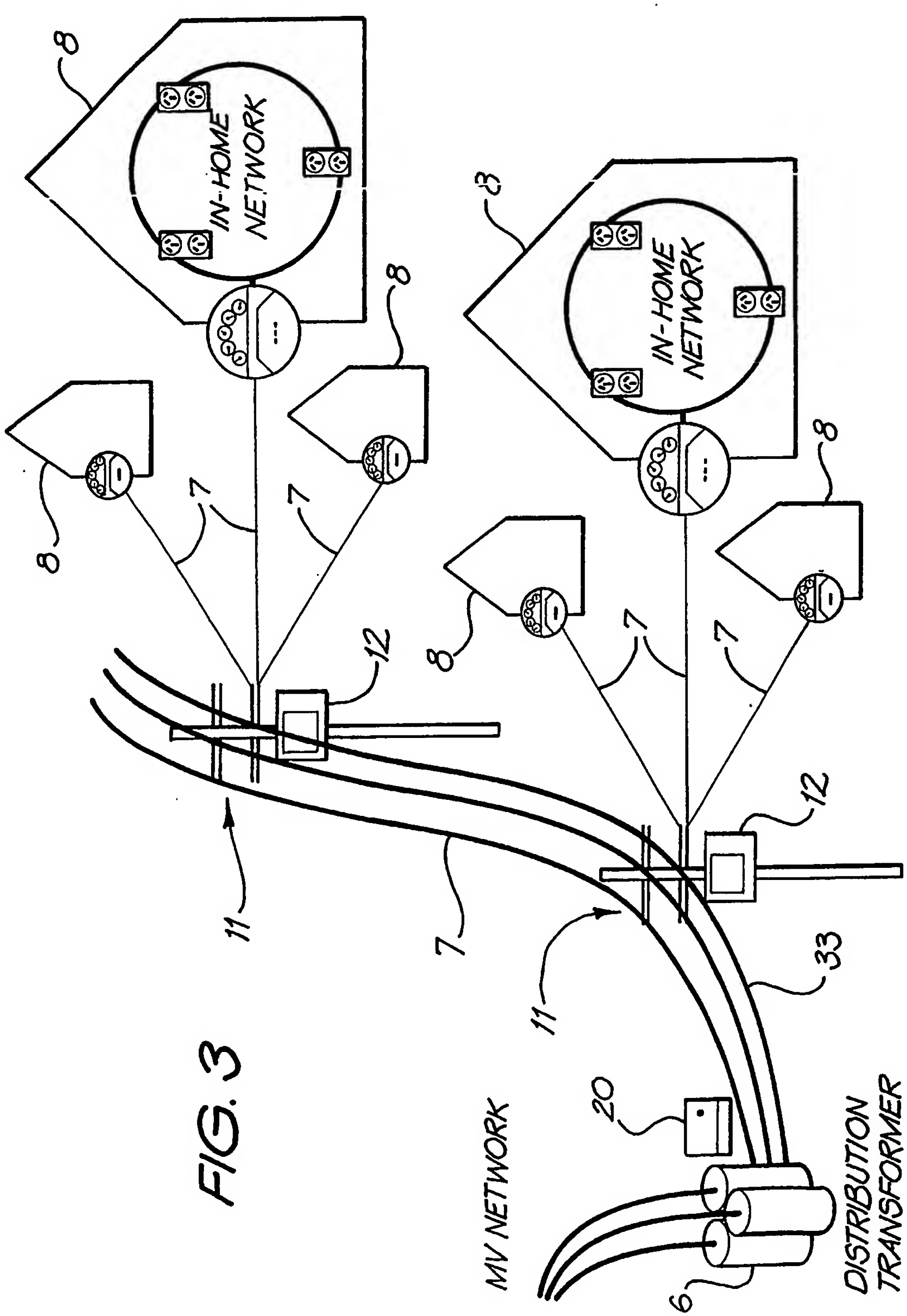
8
IN-HOME NETWORK
8
8
7
7
8
IN-HOME NETWORK
8
8
7
7
12
11
7
11
12
33
MV NETWORK
20
DISTRIBUTION TRANSFORMER
6

FIG. 3

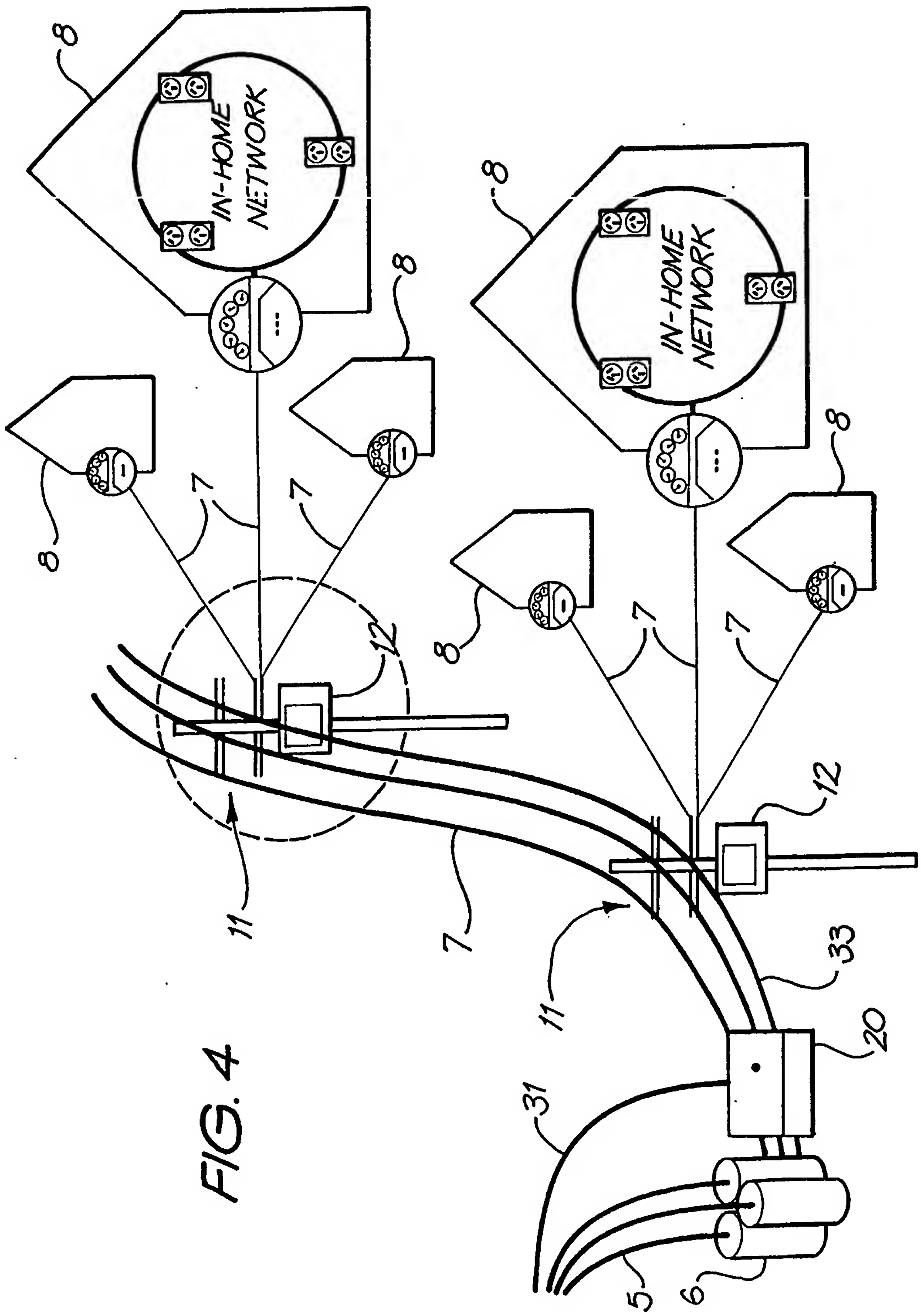

FIG. 4

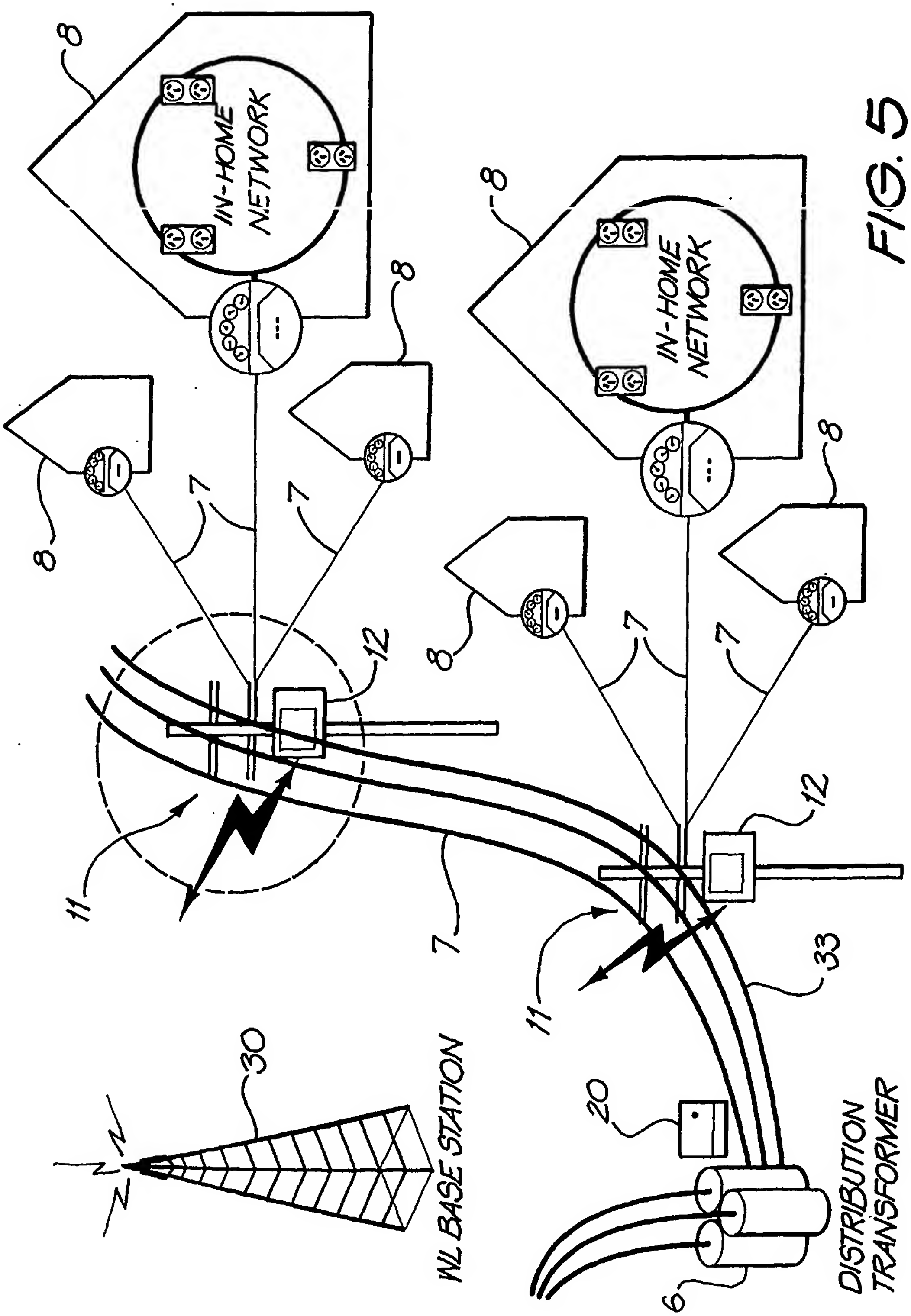
8
IN-HOME NETWORK
8
8
8
IN-HOME NETWORK
8
8
7
7
7
7
12
11
7
12
11
33
30
WL BASE STATION
20
DISTRIBUTION TRANSFORMER
6

FIG. 5

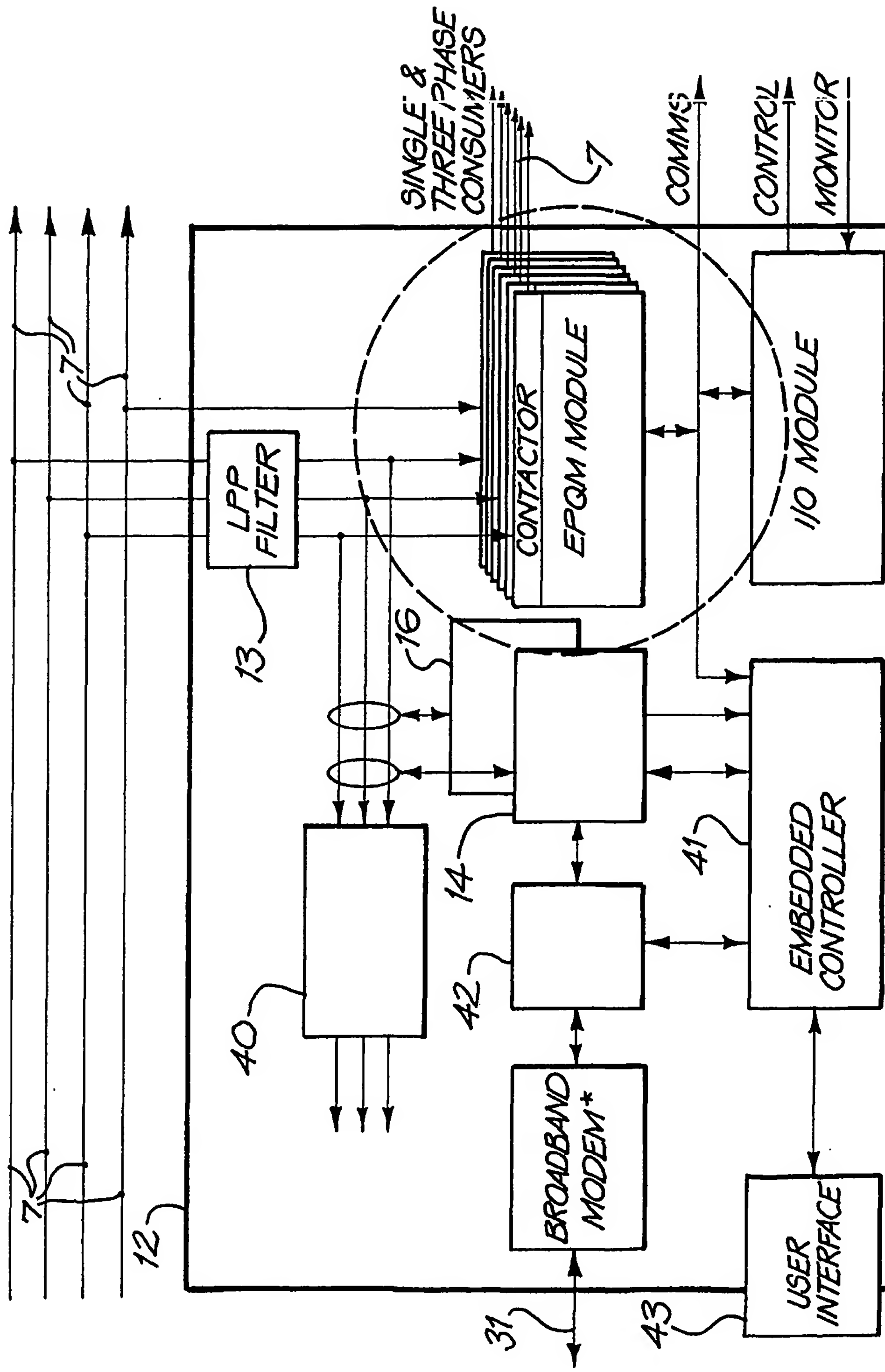
SINGLE & THREE PHASE CONSUMERS
7
COMMS
CONTROL
MONITOR
CONTACTOR
EPQM MODULE
I/O MODULE
LPP FILTER
13
16
14
41
EMBEDDED CONTROLLER
42
40
BROADBAND MODEM*
USER INTERFACE
12
31
43

FIG.6

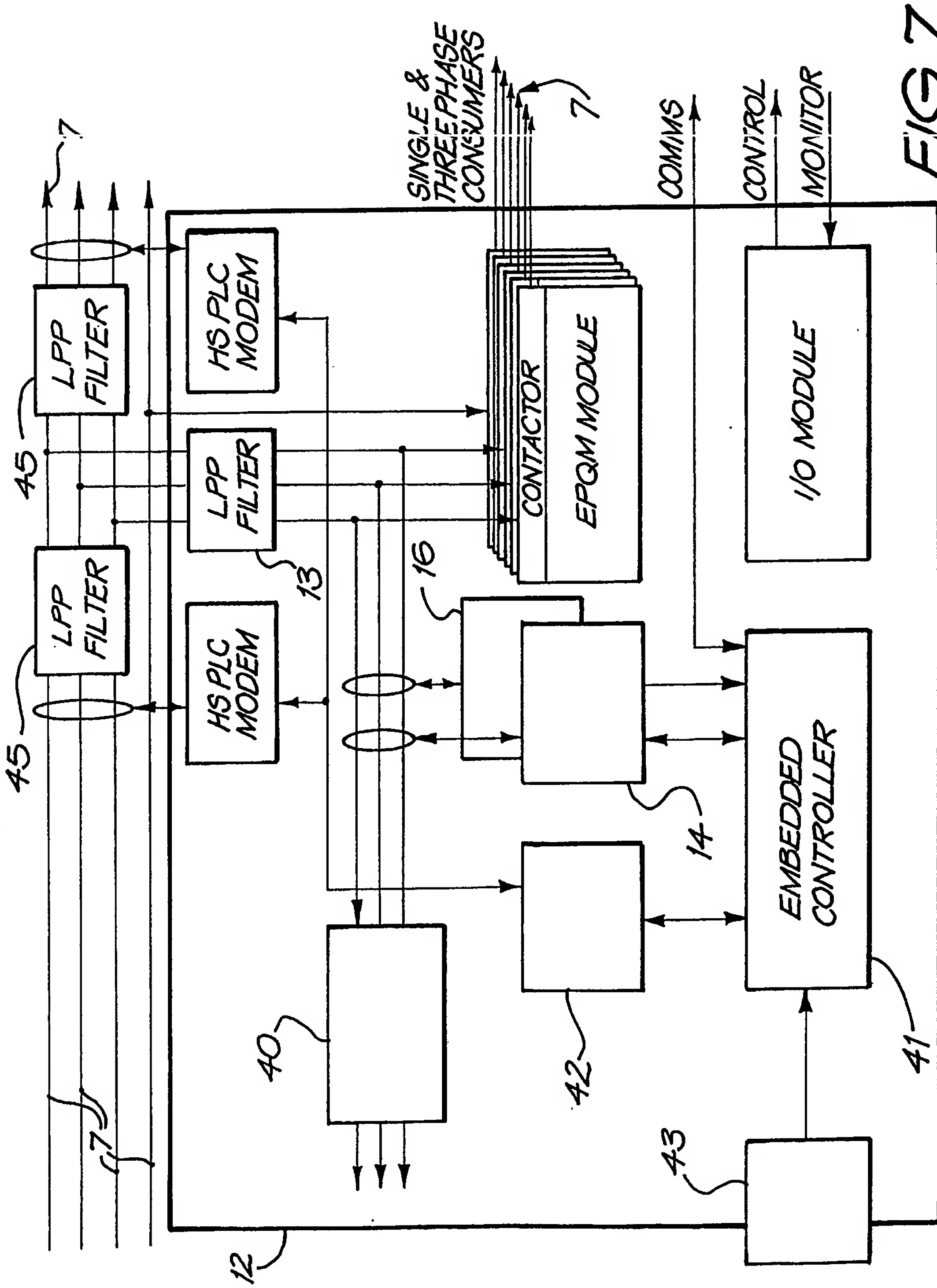
SINGLE & THREE PHASE CONSUMERS
COMMS
CONTROL
MONITOR
LPP FILTER
LPP FILTER
LPP FILTER
HS PLC MODEM
HS PLC MODEM
CONTACTOR
EPQM MODULE
I/O MODULE
EMBEDDED CONTROLLER
7
7
7
45
45
13
16
14
40
42
41
43
12

FIG. 7

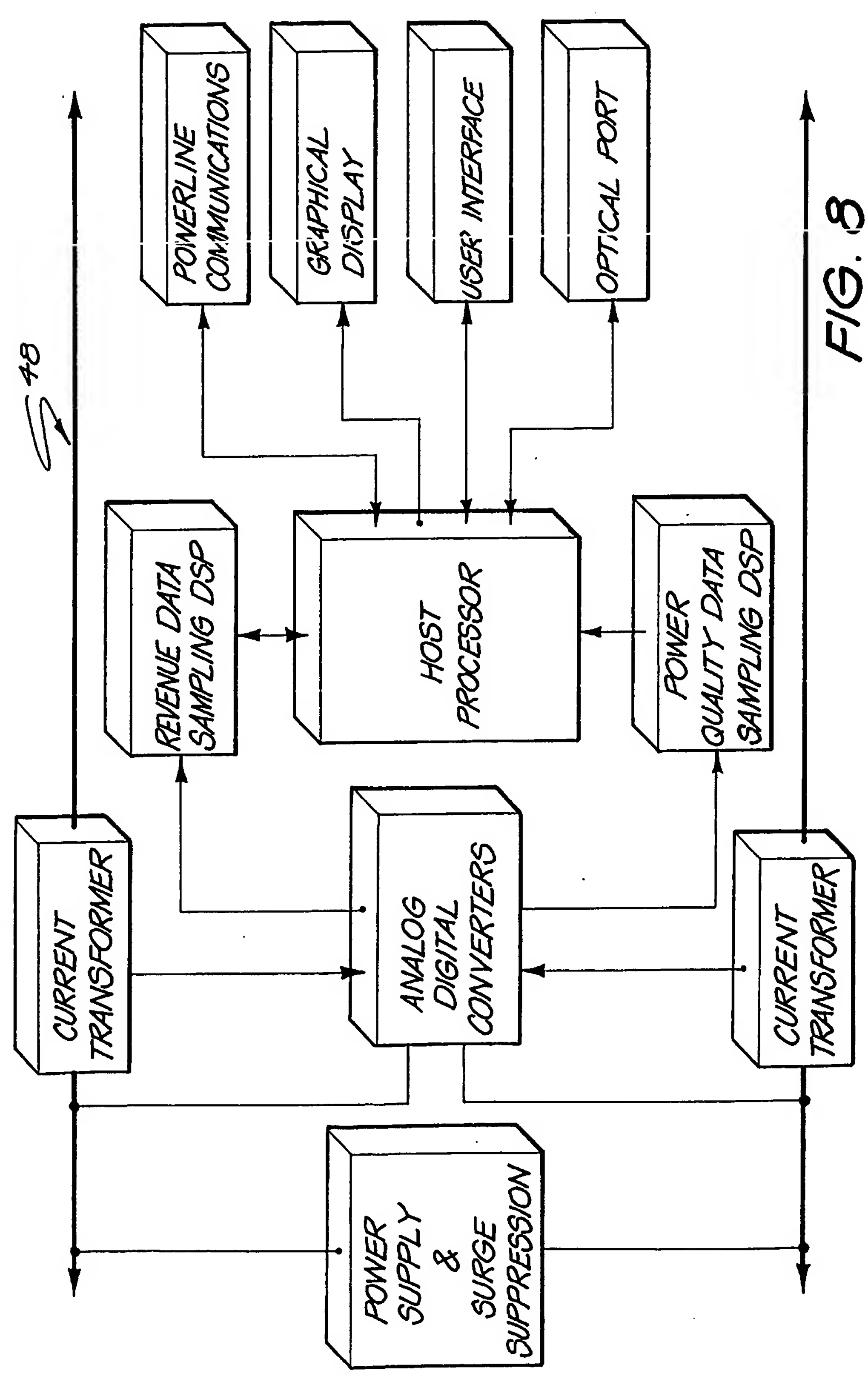
48
POWERLINE COMMUNICATIONS
GRAPHICAL DISPLAY
USER INTERFACE
OPTICAL PORT
REVENUE DATA SAMPLING DSP
HOST PROCESSOR
POWER QUALITY DATA SAMPLING DSP
CURRENT TRANSFORMER
ANALOG DIGITAL CONVERTERS
CURRENT TRANSFORMER
POWER SUPPLY & SURGE SUPPRESSION

FIG. 8

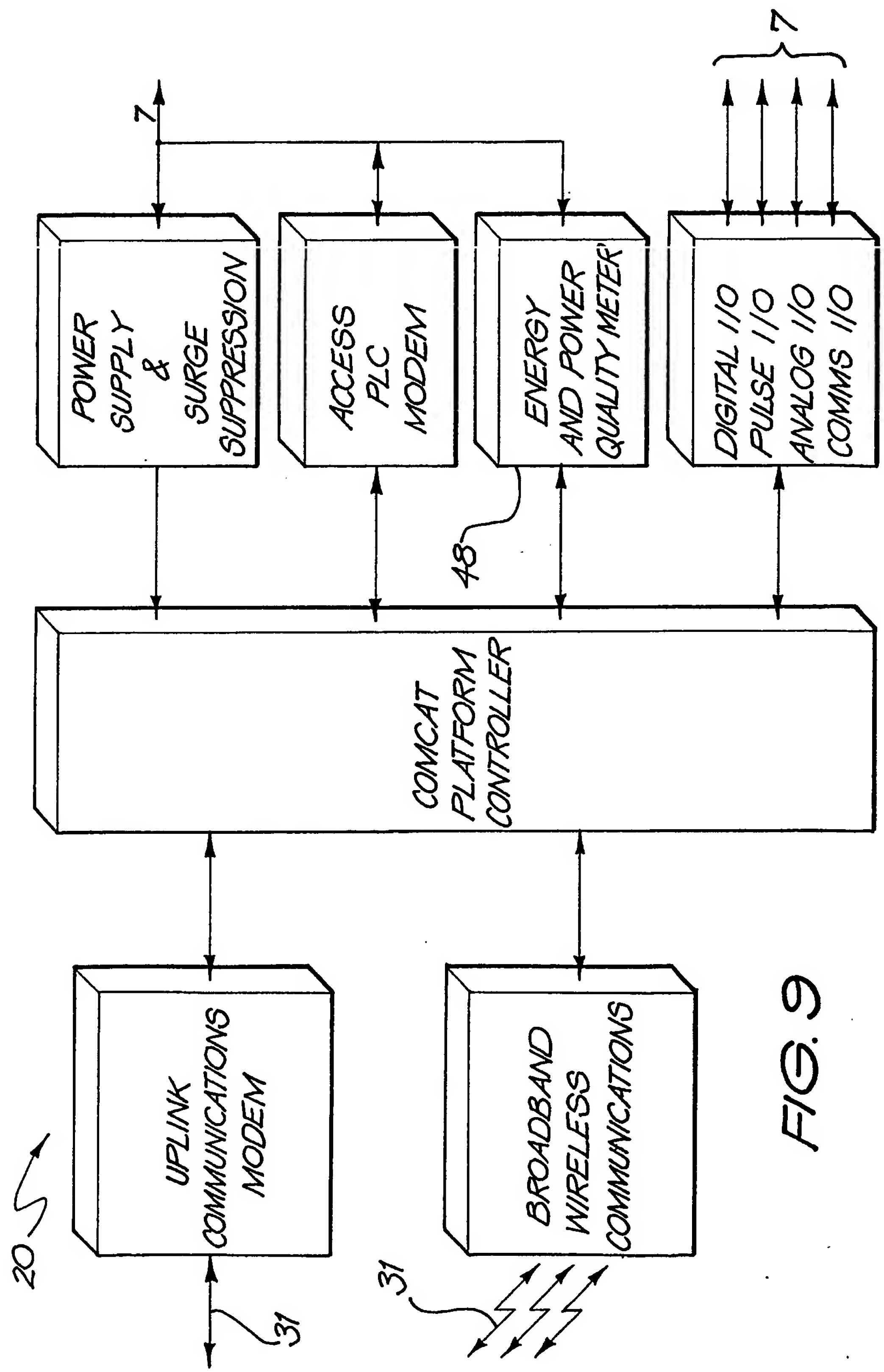
7
7
POWER SUPPLY & SURGE SUPPRESSION
ACCESS PLC MODEM
ENERGY AND POWER QUALITY METER
DIGITAL I/O
PULSE I/O
ANALOG I/O
COMMS I/O
48
COMCAT PLATFORM CONTROLLER
UPLINK COMMUNICATIONS MODEM
BROADBAND WIRELESS COMMUNICATIONS
20
31
31

FIG. 9

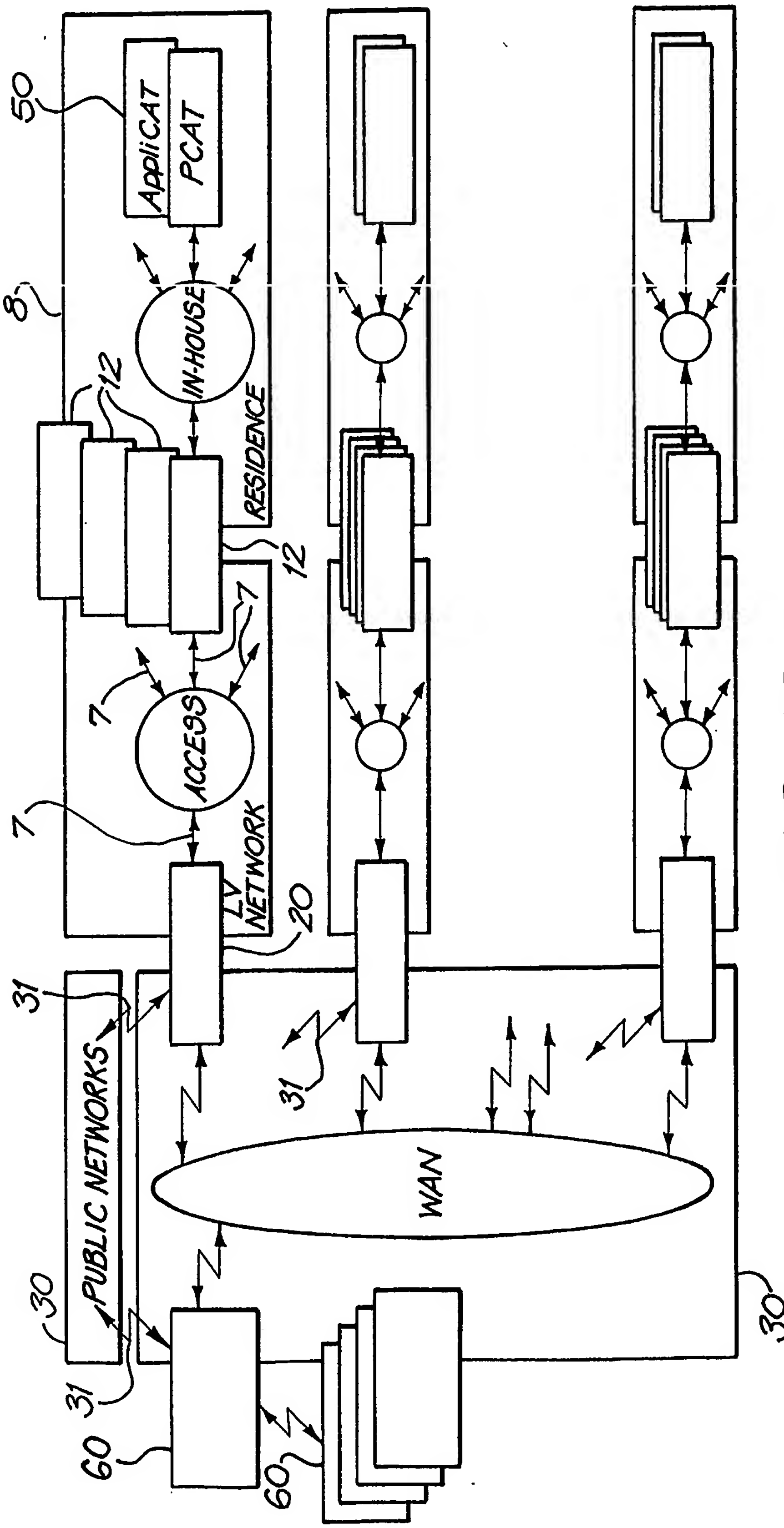
50
AppliCAT
PCAT
8
IN-HOUSE
12
RESIDENCE
12
7
ACCESS
7
7
LV NETWORK
20
31
PUBLIC NETWORKS
31
WAN
30
30
31
60
60

FIG. 10

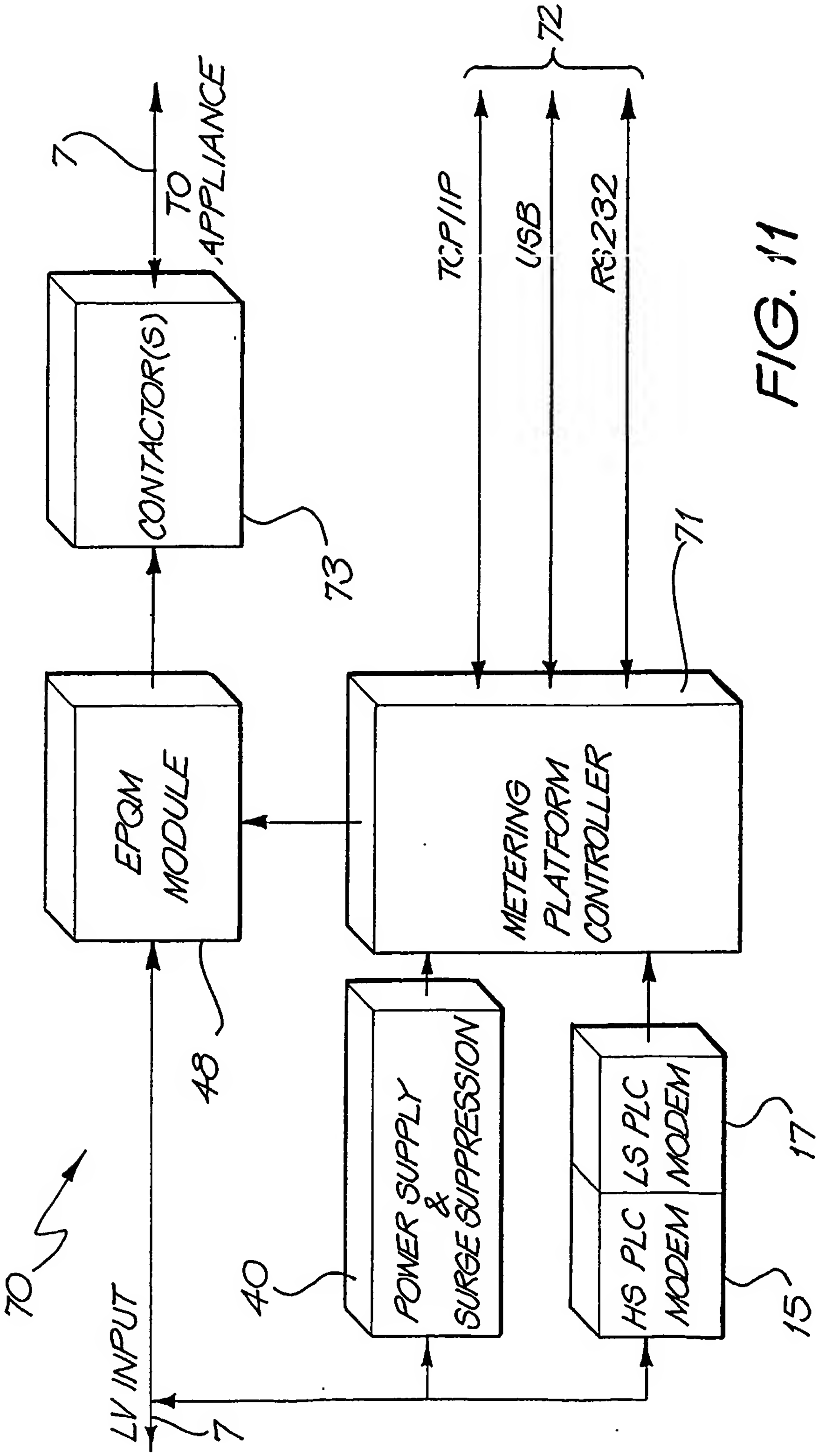
TO APPLIANCE
CONTACTOR(S)
EPQM MODULE
METERING PLATFORM CONTROLLER
TCP/IP
USB
RS232
POWER SUPPLY & SURGE SUPPRESSION
HS PLC MODEM
LS PLC MODEM
LV INPUT
7
72
73
71
48
70
40
17
15
7

FIG. 11